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DeHaan

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(54) **ABSTRACTING CLOUD MANAGEMENT**

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G06F 9/54 (2006.01)

(52) **U.S. Cl.**
CPC ***H04L 12/6418*** (2013.01); ***G06F 9/541*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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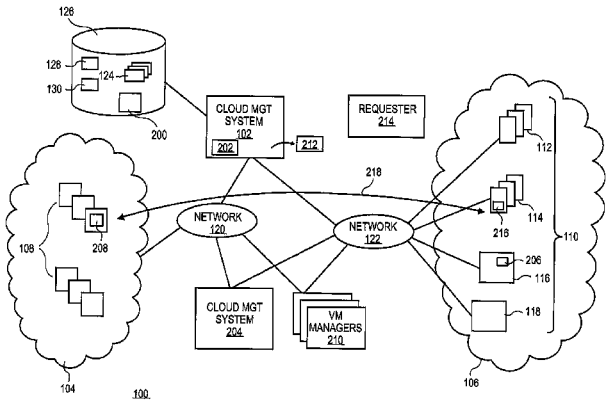
(57) **ABSTRACT**

The management of a virtual machine is disclosed. A virtual machine can be identified that is configured in accordance with a cloud management scheme. A processor of a computing system can abstract differences of management protocol between cloud management schemes. The processor can reconfigure the virtual machine in view of the abstracted differences. An instance of the reconfigured virtual machine can be created.

12 Claims, 5 Drawing Sheets



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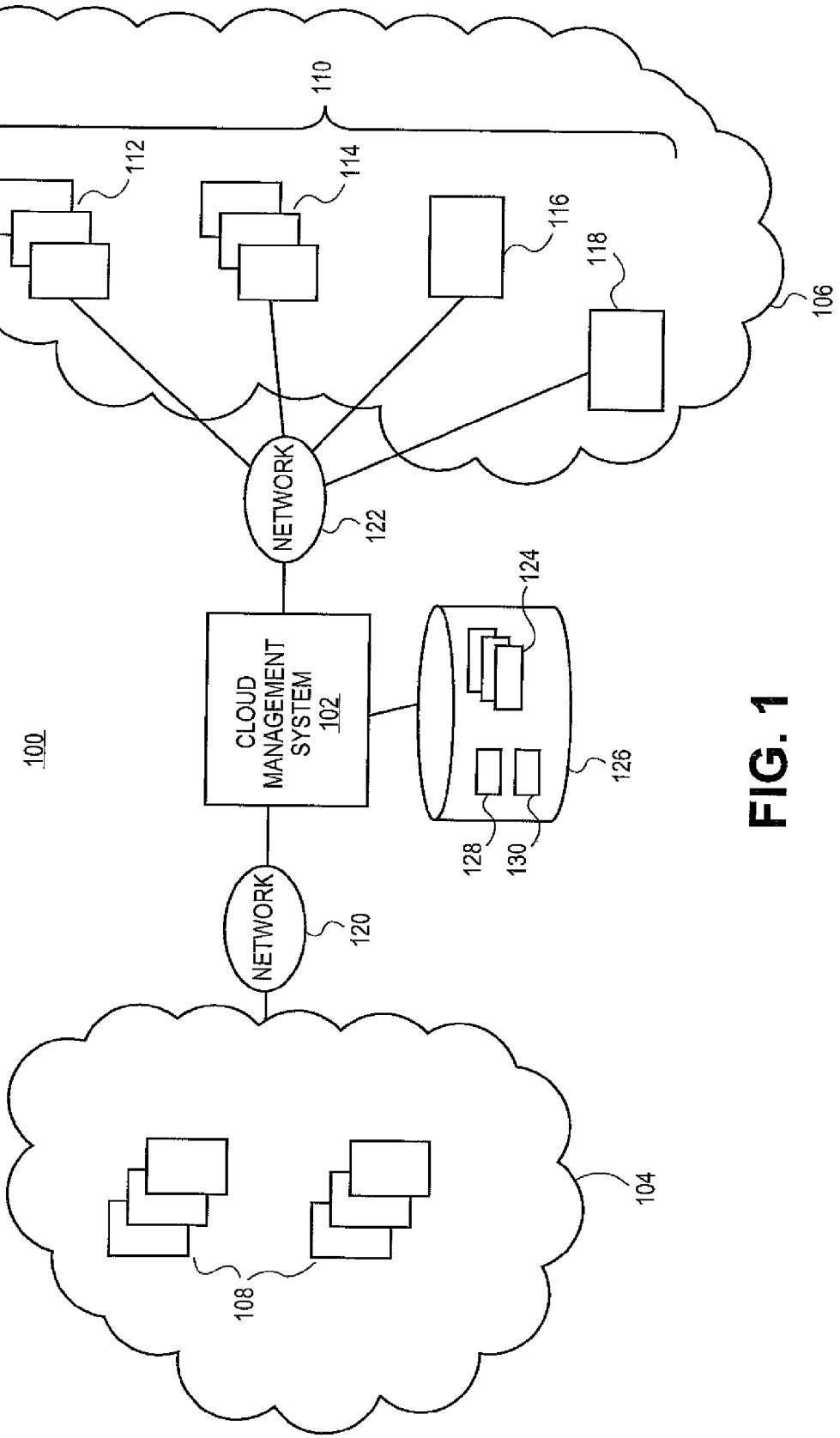
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112
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CLOUD MANAGEMENT SYSTEM 102
126
128
130
NETWORK
120
104
108
100

FIG. 1

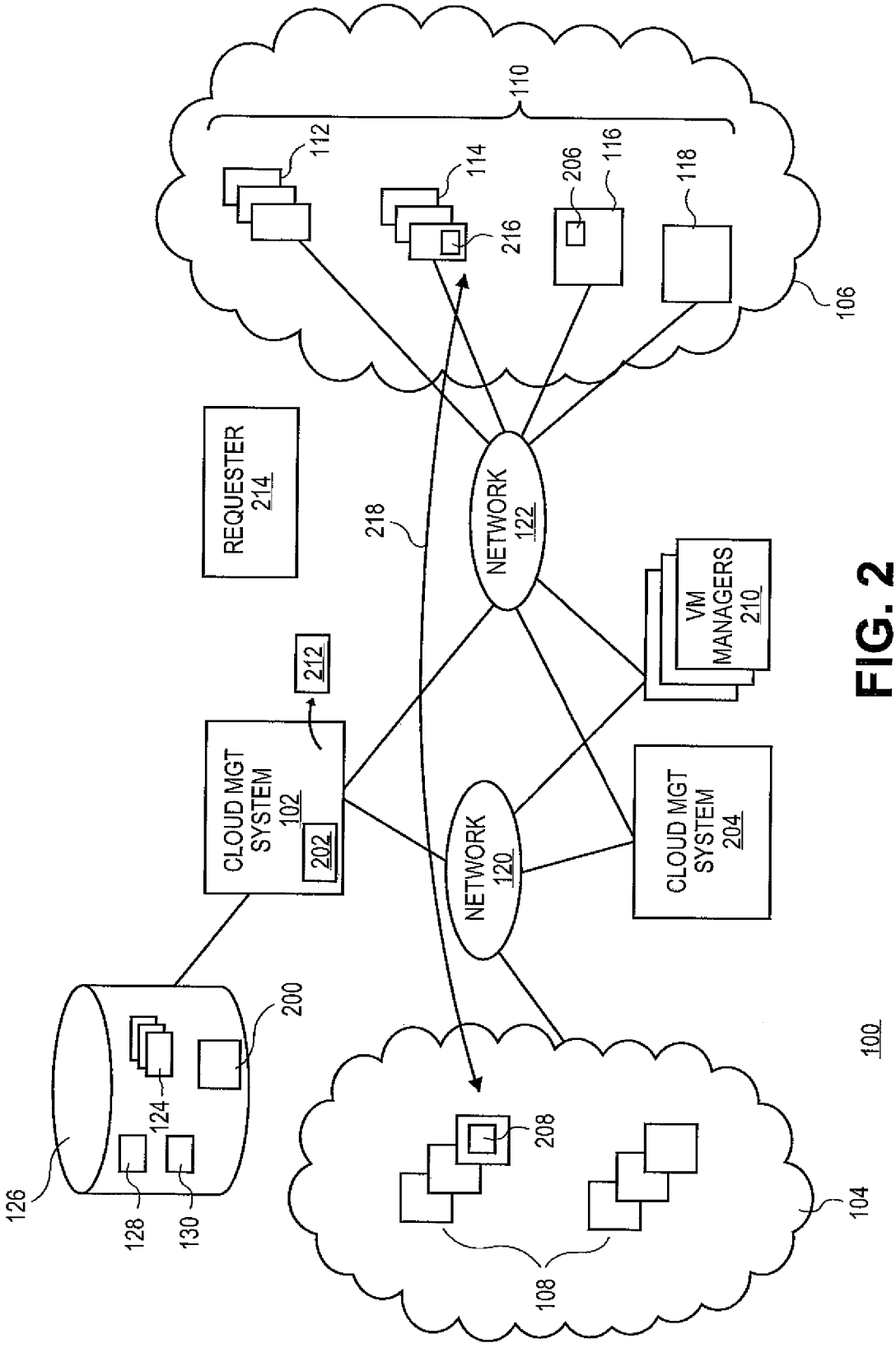
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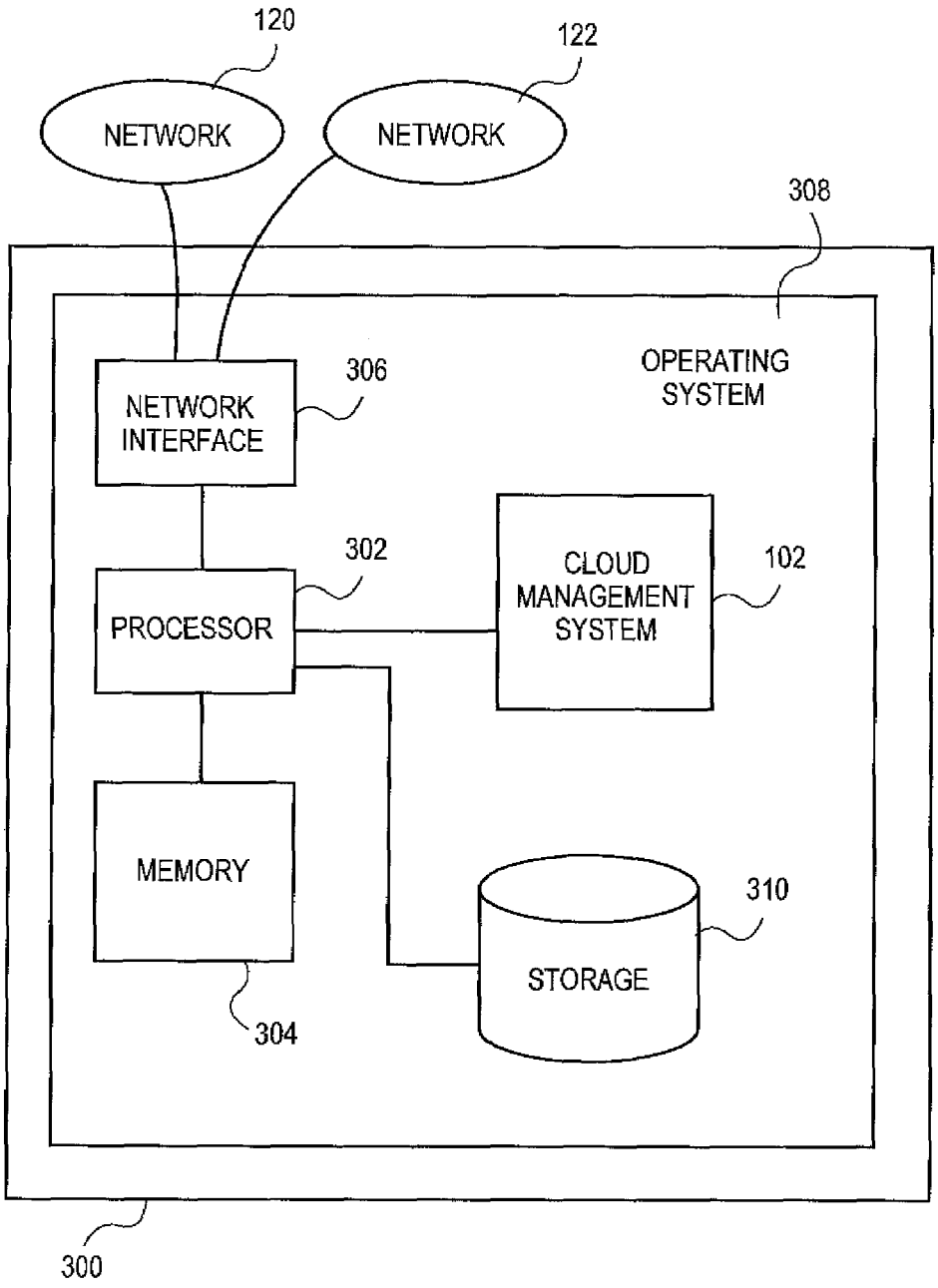
FIG. 2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MEMORY
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STORAGE
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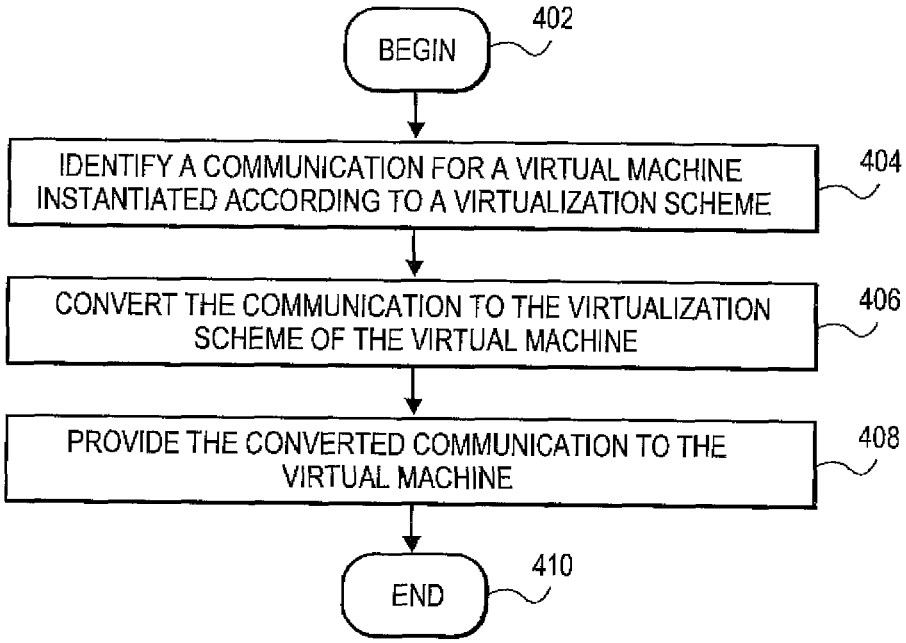
300

FIG. 3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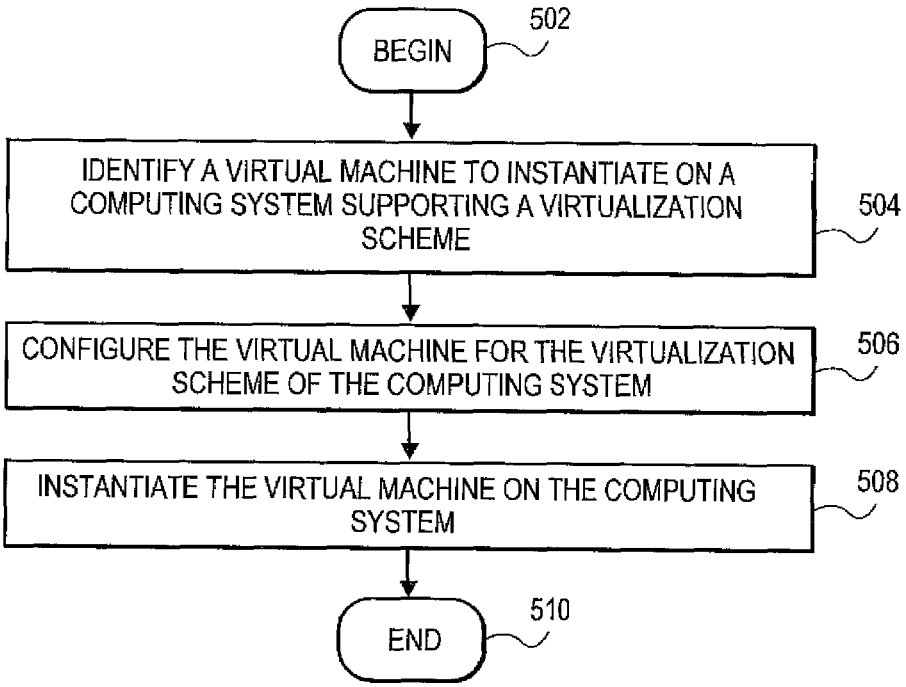
404
CONVERT THE COMMUNICATION TO THE VIRTUALIZATION SCHEME OF THE VIRTUAL MACHINE
406
PROVIDE THE CONVERTED COMMUNICATION TO THE VIRTUAL MACHINE
408
END
410

FIG. 4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IDENTIFY A VIRTUAL MACHINE TO INSTANTIATE ON A COMPUTING SYSTEM SUPPORTING A VIRTUALIZATION SCHEME
504
CONFIGURE THE VIRTUAL MACHINE FOR THE VIRTUALIZATION SCHEME OF THE COMPUTING SYSTEM
506
INSTANTIATE THE VIRTUAL MACHINE ON THE COMPUTING SYSTEM
508
END
510

FIG. 5

ABSTRACTING CLOUD MANAGEMENT

FIELD

This invention relates generally to network computing, more particularly, to systems and methods for cloud computing related networks, services and products.

DESCRIPTION OF THE RELATED ART

The advent of cloud-based computing architectures has opened new possibilities for the rapid and scalable deployment of virtual Web stores, media outlets, and other on-line sites or services. In general, a cloud-based architecture deploys a set of hosted resources such as processors, operating systems, software and other components that can be combined or strung together to form virtual machines. A user or customer can request the instantiation of a virtual machine or set of machines from those resources from a central server or management system to perform intended tasks or applications. For example, a user may wish to set up and instantiate a virtual server from the cloud to create a storefront to market products or services on a temporary basis, for instance, to sell tickets to an upcoming sports or musical performance. The user can lease or subscribe to the set of resources needed to build and run the set of instantiated virtual machines on a comparatively short-term basis, such as hours or days, for their intended application.

Currently, cloud-based computing architectures are supported by dedicated servers used solely to operate the clouds. These dedicated servers utilize unitary cloud management schemes in order to instantiate virtual machines in the cloud. As such, these architectures lack flexibility in selecting different cloud management schemes to instantiate virtual machines or communicate with the virtual machines. Likewise, these architectures lack the ability to migrate virtual machines to clouds which utilize different cloud management schemes.

BRIEF DESCRIPTION OF THE DRAWINGS

Various features of the embodiments can be more fully appreciated, as the same become better understood with reference to the following detailed description of the embodiments when considered in connection with the accompanying figures, in which:

FIG. **1** illustrates an exemplary cloud computing architecture in which various embodiments of the present teachings can be practiced;

FIG. **2** illustrates the exemplary cloud computing architecture in which a cloud management system can utilize an abstraction library to manage a cloud, according to various embodiments;

FIG. **3** illustrates an exemplary hardware configuration for a cloud management system, according to various embodiments;

FIG. **4** illustrates a flowchart of an exemplary process for managing a cloud, according to various embodiments; and

FIG. **5** illustrates a flowchart of another exemplary process for managing a cloud, according to various embodiments.

DETAILED DESCRIPTION OF EMBODIMENTS

For simplicity and illustrative purposes, the principles of the present teachings are described by referring mainly to exemplary embodiments thereof. However, one of ordinary skill in the art would readily recognize that the same principles are equally applicable to, and can be implemented in, all types of information and systems, and that any such variations do not depart from the true spirit and scope of the present teachings. Moreover, in the following detailed description, references are made to the accompanying figures, which illustrate specific embodiments. Electrical, mechanical, logical and structural changes may be made to the embodiments without departing from the spirit and scope of the present teachings. The following detailed description is, therefore, not to be taken in a limiting sense and the scope of the present teachings is defined by the appended claims and their equivalents.

Embodiments of the present teachings relate to systems and methods for flexible management of a cloud computing environment. More particularly, embodiments relate to platforms and techniques in which a cloud management system can support one or more clouds regardless of the cloud management scheme utilized in the cloud.

According to embodiments, to manage and instantiate the virtual machines regardless of the cloud management scheme of clouds, the cloud management system can be configured to utilize an abstraction library. The abstraction library can be configured to abstract out the differences between different cloud management schemes. The abstraction library can be configured to include a record of the different formats utilized by the cloud management schemes in order to allow communication, control, instantiation, and management of the virtual machines. Additionally, the abstraction library can be configured to include commands and software instructions to convent and to configure the format of one cloud management scheme to another cloud management scheme.

According to embodiments, the abstraction library can be implemented as any type of software library accessible by the cloud management system, management tools of the cloud management system, and other systems and application programs. The cloud management system can be configured to maintain the abstraction library in a repository or storage.

According to embodiments, the cloud management system can be configured to utilize the abstraction library to perform various processes associated with the virtual machines regardless of the cloud management scheme of the virtual machine. The cloud management system can be configured to format and to convert virtual machines to the cloud management scheme of the cloud in which the virtual machine will be instantiated. Likewise, the cloud management system can be configured to utilize the abstraction library to enable communication with virtual machines that are formated according to a different cloud management scheme than the communication.

By supporting clouds regardless of the infrastructure and cloud management scheme, the cloud management system can create, manage, and support the clouds on any type of computing resources. Likewise, the cloud management system can support virtual machines and clouds of different cloud management schemes. Thus, the cloud management system can provide flexibility and efficiency to any cloud computing environment.

FIG. **1** illustrates an overall cloud computing environment **100**, in which systems and methods for the flexible management of the cloud computing environment **100**, according to embodiments of the present teachings. According to embodiments, a cloud management system **102** can be configured to mange one or more clouds, such as a dedicated cloud **104** and an ad-hoc cloud **106**. As used herein, a

"cloud" can comprise a collection of computing resources that can be invoked to instantiate a virtual machine, process, or other resource for a limited or defined duration.

As shown for example in FIG. **1**, the collection of computing resources supporting the dedicated cloud **104** can comprise a set of resource servers **108** configured to deliver computing resources and components needed to instantiate a virtual machine, process, or other resource. For example, one group of resource servers can host and serve an operating system or components thereof to deliver to and instantiate a virtual machine. Another group of resource servers can accept requests to host computing cycles or processor time, to supply a defined level of processing power for a virtual machine. A further group of resource servers can host and serve applications to load on an instantiation of a virtual machine, such as an email client, a browser application, a messaging application, or other applications or software. Other types of resource servers are possible.

In embodiments, in addition to supporting the dedicated cloud **104**, the cloud management system **102** can be configured to support the ad-hoc cloud **106**. The ad-hoc cloud **106** can be composed of a variety of computing resources that may not be dedicated to a cloud but can have available computing resources to contribute to the ad-hoc cloud **106**. For example, a corporation or university can have a large number of computing resources that support a variety of process (email, websites, individual user computing, and the like). The corporation or university can utilize the available excess computing resources to support an ad-hoc cloud, such as ad-hoc cloud **106**.

In embodiments, as shown in FIG. **1**, the ad-hoc cloud **106** can be supported by a number of computing systems **110**. For example, the computing systems **110** can include a variety of systems such as a set of servers **112** and **114** and standalone user computing systems **116** and **118**. The computing systems **110** can include hardware resources, such as processors, memory, network hardware, storage devices, and the like, and software resources, such as operating systems (OS), application programs, and the like.

In embodiments, the entire set of resource servers **108** or other hardware or software resources used to support the cloud **104** and the computing systems **110** used to support the cloud **106** can be managed by the cloud management system **102**. The cloud management system **102** can comprise a dedicated or centralized server and/or other software, hardware, and network tools that communicate via one or more networks **120** and networks **122**, such as the Internet or other public or private network, with all sets of resource servers **108** to manage the cloud **104** and with computing systems **110** to manage the cloud **106** and their operation.

In embodiments, to manage the clouds **104** and **106**, the cloud management system **102** can be configured identify the computing resources of the set of resource servers **108** and computing systems **110**. The cloud management system **102** can be configured to include a network management agent that is capable of querying the set of resource servers **108** and computing systems **110** to determine the hardware and software resources. Likewise, the cloud management system **102** can be configured to communicate with external network management systems and/or resources monitoring agents executing on the set of resource servers **108** and computing systems **110** in order to determine the hardware and software resources of the set of resource servers **108** and computing systems **110**.

In embodiments, the cloud management system **102** can be configured to identify both the hardware and software resources of the set of resource servers **108** and computing systems **110** and which of those resources are available for use in the cloud. The cloud management system **102** can be configured to identify the hardware resources such as type and amount of processing power, type and amount of memory, type and amount of storage, type and amount of network bandwidth and the like, of the set of resource servers **108** and computing systems **110**. Likewise, the cloud management system can be configured to identify the software resources, such as type of OS, application programs, and the like, of the set of resource servers **108** and computing systems **110**.

In embodiments, once the computing resources have been identified, the cloud management system **102** can be configured to store an identification of the available resources in an inventory **124** in a repository **126**. The repository **126** can be any type of structure configured to store information, such as a database. The repository **126** can be maintained in a computer readable storage device or medium whether local to or remote from the cloud management system **102**.

In embodiments, the inventory **124** can be configured to include information that identifies the set of resource server **108** and computing systems **110** and information identifying the computing resources available. The sets of resource servers **108** and each system in the computing systems **110** can be identified by unique identifiers such as, for instance, Internet Protocol (P) addresses or other addresses. In the inventory **124**, the cloud management system **102** can associate, with each unique identifier, the computing resources available on that computing system.

In embodiments, to instantiate a new set of virtual machines, a requester can transmit an instantiation request to the cloud management system **102**. The instantiation request can include the specifications for the set of virtual machines. The specifications can include the particular type of virtual machine they wish to invoke for their intended application. A requester can, for instance, make a request to instantiate a set of virtual machines configured for email, messaging or other applications from the cloud **104** and/or **106**. The specifications can also include the type and/or amount of computing resources required. For example, the instantiation request can specify an amount of processing power or input/output (I/O) throughput the user wishes to be available to each instance of the virtual machine or other resources.

In embodiments, the requester's instantiation request can specify a variety of other specifications defining the configuration and operation of the set of virtual machines to be invoked. The instantiation request, for example, can specify a defined period of time for which the instantiated machine or process is needed. The period of time can be, for example, an hour, a day, or other increment of time. In embodiments, the requester's instantiation request can specify the instantiation of a set of virtual machines or processes on a task basis, rather than for a predetermined amount of time. For instance, a requester could request resources until a software update is completed. The requester can also, for instance, specify a service level agreement (SLA) acceptable for their application. One skilled in the art will realize that the requester's request can likewise include combinations of the foregoing exemplary specifications, and others.

In embodiments, the instantiation request can be received and processed by the cloud management system **102**, which identifies the type of virtual machine, process, or other resource being requested from the specifications. The cloud management system **102** can then identify the collection of computing resources necessary to instantiate that machine or resource. For example, the set of instantiated virtual

machines or other resources can for example comprise virtual transaction servers used to support Web storefronts, or other transaction sites.

In embodiments, the cloud management system **102** can be configured to utilize the specifications from the instantiation request and the inventory **124** of available computing resources to determine which cloud resources to devote to the requester's virtual machines to maximize the computing resources of the clouds **104** and/or **106** and meet the requester's specifications. For example, the cloud management system **102** can select a group of servers in the set of resource servers **108** and/or computing system in the computing systems **110** that match or best match the instantiation request for each component needed to build the virtual machine or other resource.

In embodiments, the cloud management system **102** can maintain a set of "virtual groups," and assign the set of resource servers **108** and computing systems **110** to different "virtual groups". The "virtual groups" can be based on the particular usage (type of virtual machine, application of the virtual machine, function of the virtual machine, and the like) of the members in the groups. For example, the cloud management system **102** can set up a "virtual group" for web servers. The cloud management system **102** can classify the computing resources for the web server "virtual group" based on which computing resources are best suited for web servers. As members of the web server "virtual group" request use of the cloud, the cloud management system **102** can assign the available computing resources classified in the web server "virtual group" to the members. Likewise, the "virtual groups" can be based on the specifications of the computing resources (type and amount of computing resources). For example, the cloud management system **102** can create a "virtual group" for high power computing users. The cloud management system **102** can assign resources to this group that can adequately support computing intensive virtual machines. As members of the high power "virtual group" request use of the cloud, the cloud management system **102** can assign the available computing resources classified in the high power "virtual group" to the members. The cloud management system **102** can maintain the virtual groups in a group record **128** in repository **126**.

When the request to instantiate a set of virtual machines or other resources has been received and the necessary resources to build that machine or resource have been identified, the cloud management system **102** can communicate with one or more set of resource servers **108** and/or computing systems **110** to locate resources to supply the required components. The cloud management system **102** can select providers from the diverse set of resource servers **108** and/or computing systems **110** to assemble the various components needed to build the requested set of virtual machines or other resources. It may be noted that in some embodiments, permanent storage such as hard disk arrays may not be included or located within the set of resource servers **108** and the computing resources **110** available to the cloud management system **102**, because the set of instantiated virtual machines or other resources may be intended to operate on a purely transient or temporary basis. In embodiments, other hardware, software or other resources not strictly located or hosted in the cloud can be leveraged as needed. For example, other software services that are provided outside of the clouds **104** and **106** and hosted by third parties can be invoked by in-cloud virtual machines. For further example, other non-cloud hardware and/or storage services can be utilized as an extension to the clouds **104** and **106**, either on an on-demand or subscribed or decided basis.

With the specification and resources identified, the cloud management system **102** can extract and build the set of virtual machines or other resources on a dynamic or on-demand basis. For example, one set of resource servers **108** or computing systems **110** can respond to an instantiation request for a given quantity of processor cycles with an offer to deliver that computational power immediately and guaranteed for the next hour. A further set of resource servers **108** or computing systems **110** can offer to immediately supply communication bandwidth, for example on a guaranteed minimum or best-efforts basis. In other embodiments, the set of virtual machines or other resources can be built on a batch basis or at a particular future time. For example, a set of resource servers **108** and/or computing systems **110** can respond to a request for instantiation at a programmed time with an offer to deliver the specified quantity of processor cycles within a specific amount of time, such as the next 12 hours.

In embodiments, the cloud management system **102** can then coordinate the integration of the completed group of servers from the set of resource servers **108** and/or computing systems from the computing systems **110**, to build and launch the requested set of virtual machines or other resources. The cloud management system **102** can track the combined group of servers selected from the set of resource servers **108**, computing systems from the computing systems **110**, or other distributed resources that are dynamically or temporarily combined, to produce and manage the requested virtual machine population or other resources.

In embodiments, the cloud management system **102** can then set up and launch the initiation process for the virtual machines, processes, or other resources to be delivered from the cloud. The cloud management system **102** can for instance transmit an instantiation command or instruction to the group of servers in set of resource servers **108** and/or computing system in the computing systems **110**. The cloud management system **102** can receive a confirmation message back from each participating server in a set of resource servers **108** and/or computing system in the computing systems **110** indicating a status regarding the provisioning of their respective resources. Various sets of resource servers can confirm, for example, the availability of a dedicated amount of processor cycles, amounts of electronic memory, communications bandwidth, or applications or other software prepared to be served.

In embodiments, the cloud management system **102** can maintain a VM record **130** of each virtual machine instantiated in the clouds **104** and **106**. Each virtual machine can be assigned an instantiated machine ID that can be stored in the VM record **130**, or other record or image of the instantiated population. Additionally, the cloud management system **102** can store the duration of each virtual machine and the collection of resources utilized by each virtual machine in the VM record **130** and/or inventory **124**. The cloud management system **102** can maintain the VM record **130** in the repository **126**.

In embodiments, the cloud management system **102** can further store, track and manage a requester's identity and associated set of rights or entitlements to software, hardware, and other resources. Each requester that populates a set of virtual machines in the cloud can have specific rights and resources assigned and made available to them. The cloud management system **102** can track and configure specific actions that a requester can perform, such as provision a set of virtual machines with software applications or other resources, configure a set of virtual machines to desired specifications, submit jobs to the set of virtual

machines or other host, manage other requesters of the virtual machines or other resources, and other privileges or actions. The cloud management system **102** can further generate records of the usage of instantiated virtual machines to permit tracking, billing, and auditing of the services consumed by the requester. In embodiments, the cloud management system **102** can for example meter the usage and/or duration of the virtual machines, to generate subscription billing records for a requester that has launched those machines. Other billing or value arrangements are possible.

The cloud management system **102** can configure each virtual machine to be made available to requester and/or users of the one or more networks **120** and/or **122** via a browser interface, or other interface or mechanism. Each instantiated virtual machine can communicate with the cloud management system **102** and the underlying registered set of resource servers **108** and/or computing systems **110** via a standard Web application programming interface (API), or via other calls or interfaces. The instantiated virtual machines can likewise communicate with each other, as well as other sites, servers, locations, and resources available via the Internet or other public or private networks, whether within a given cloud **104** or **106** or between clouds.

It may be noted that while a browser interface or other front-end can be used to view and operate the instantiated virtual machines from a client or terminal, the processing, memory, communications, storage, and other hardware as well as software resources required to be combined to build the virtual machines or other resources are all hosted remotely in the clouds **104** and **106**. In embodiments, the virtual machines or other resources may not depend on or require the requester's own on-premise hardware or other resources. In embodiments, a requester can therefore request and instantiate a set of virtual machines or other resources on a purely off-premise basis, for instance to build and launch a virtual storefront or other application.

Because the cloud management system **102** in one regard specifies, builds, operates and manages the virtual machines on a logical level, the requester can request and receive different sets of virtual machines and other resources on a real-time or near real-time basis, without a need to specify or install any particular hardware. The requester's virtual machines, processes, or other resources can be scaled up or down immediately or virtually immediately on an on-demand basis, if desired. In embodiments, the various sets of computing resources that are accessed by the cloud management system **102** to support the virtual machines or processes can change or be substituted, over time. The type and operating characteristics of the virtual machines can nevertheless remain constant or virtually constant, since instances are assembled from abstracted resources that can be selected and maintained from diverse sources based on uniform specifications.

In terms of network management of the virtual machines that have been successfully configured and instantiated, the cloud management system **102** can perform various network management tasks including security, maintenance, and metering for billing or subscription purposes. The cloud management system **102** of a given cloud **104** or **106** can, for example, install or terminate applications or appliances on individual machines. The cloud management system **102** can monitor operating virtual machines to detect any virus or other rogue process on individual machines, and for instance terminate the infected application or vial machine. The cloud management system **102** can likewise manage the virtual machines or other resources on a collective basis, for instance, to push or deliver a software upgrade to all active virtual machines. Other management processes are possible. Likewise, the cloud management system **102** can be configured to communicate with external network management systems to coordinate the network management functions and processes.

In embodiments, more than one set of virtual machines can be instantiated in a given cloud at the same, overlapping or successive times. The cloud management system **102** can, in such implementations, build, launch and manage multiple sets of virtual machines based on the same or different underlying set of resource servers **108** or computing systems **110**, with populations of different sets of virtual machines such as may be requested by different requesters. The cloud management system **102** can institute and enforce security protocols in the clouds **104** and **106** hosting multiple sets of virtual machines. Each of the individual sets of virtual machines can be hosted in a respective partition or sub-cloud of the resources of the clouds **104** and/or **106**. The cloud management system **102** of a cloud can for example deploy services specific to isolated or defined sub-clouds, or isolate individual workloads/processes within the cloud to a specific sub-cloud. The subdivision of the clouds **104** and/or **106** into distinct transient sub-clouds or other sub-components which have assured security and isolation features can assist in establishing multiple requesters or a multi-tenant cloud arrangement. In a multiple requesters scenario, each of the multiple requesters can use the cloud platform as a common utility while retaining the assurance that their information is secure from other requesters of the overall cloud system. In further embodiments, sub-clouds can nevertheless be configured to share resources, if desired.

In embodiments, the instantiated virtual machines supported by the cloud **104** can also interact with instantiated virtual machines or processes generated in the cloud **106** or other clouds and vice versa. The cloud management system **102** of clouds **104** and **106** can interface with the cloud management system of other clouds, to coordinate those domains and operate the clouds and/or virtual machines or processes on a combined basis.

As described above, the cloud management system **102** can instantiate and manage the virtual machines instantiated in the clouds **104** and **106**. In embodiments, the instantiation and management of virtual machines can be performed by virtual machine (VM) managers separate from the cloud management system **102**. The cloud management system **102** can be configured to communicate with the separate VM managers in order to provide the VM managers with the computing resources available in the clouds **104** and **106**. The cloud management system **102** can be configured to communicate and cooperate with the VM managers regardless of the cloud management scheme used by the VM managers.

In the foregoing and other embodiments, the requester making an instantiation request or otherwise accessing or utilizing the cloud network can be a person, customer, subscriber, administrator, corporation, organization, or other entity. In embodiments, the requester can be or include another virtual machine, application or process. In further embodiments, multiple requesters and/or entities can share the use of a set of virtual machines or other resources.

FIG. **2** further illustrates aspects of the cloud computing environment **100** in which the cloud management system **102** can manage the dedicated cloud **104** and the ad-hoc cloud **106** utilizing an abstraction library **200**, according to various embodiments. While FIG. **2** only illustrates the interaction of cloud management system **102** with the dedi-

cated cloud **104** and the ad-hoc cloud **106**, one skilled in the art will realize that the cloud management system **102** can manage any number of clouds, for instance, only one of the dedicated cloud **104** and the ad-hoc cloud **106** or other clouds in addition to the dedicated cloud **104** and the ad-hoc cloud **106**.

As shown in FIG. **2**, the cloud management system **102** can be coupled to a network **120** to communicate with the set of resource servers **108** and coupled to the network **122** to communicate with computing systems **110** to provide management services for the dedicated cloud **104** and the ad-hoc cloud **106**. As mentioned above, the dedicated cloud **104** can comprise a set of resource servers **108** configured to deliver computing resources and components needed to instantiate a virtual machine, process, or other resource. The ad-hoc cloud **106** can be composed of a variety of computing resources that may not be dedicated to a cloud but can have available computing resources to contribute to the ad-hoc cloud **106**. For example, a corporation or university can have a large number of computing resources that support a variety of processes (email, websites, individual user computing, and the like). The corporation or university can utilize the available excess computing resources to support the ad-hoc cloud **106**.

In embodiments, as shown in FIG. **2**, the ad-hoc cloud **106** can be supported by the computing systems **110**. For example, the computing systems **110** can include a variety of systems such as a set of servers **112** and **114** and standalone user computing systems **116** and **118**. The computing systems **110** can include hardware resources, such as processors, memory, network hardware, storage devices, and the like, and software resources, such as operating systems (OS), application programs, and the like.

In embodiments, to manage and support the dedicated cloud **104** and the ad-hoc cloud **106**, the cloud management system **102** can be configured to identify the computing resources of the set of resources servers **108** and the computing systems **110**. The cloud management system **102** can be configured to include a network management agent **202** that is capable of querying the set of resource servers **108** and the computing systems **110** to determine the hardware and software resources. Likewise, the network management agent **202** can be configured to directly examine the set of resource servers **108** and the computing systems **110** to determine the computing resources. The network management agent **202** can be configured to include the necessary logic, routines, instruction, and commands to communicate with the set of resource servers **108** and the computing systems **110** in order to identify the computing resources of the set of resource servers **108** and the computing systems **110**.

In embodiments, the network management agent **202** can be implemented as a portion of the code for the cloud management system **102**. Likewise, the network management agent **202** can be implemented as a separate software tool accessible by the cloud management system **102**. The network management agent **202** can be written in a variety of programming languages, such as JAVA, C++, Python code, and the like to accommodate a variety of operating systems, machine architectures, etc. Additionally, the network management agent **202** can be configured to include the appropriate application programming interfaces (APIs) to communicate with and cooperate with other components of the cloud management system **102**.

In embodiments, the cloud management system **102** can be configured to communicate with an external network management system **204** in order to determine the computing resources of the set of resource servers **108** and the computing systems **110**. The cloud management system **102** can be configured to send a request to the network management system **204** to identify the computing resources. The network management system **204** can be configured to transmit a query to the set of resource servers **108** via network **120** and to the computing systems **110** via network **122**, to receive a response identifying the computing resources of the set of resource servers **108** and the computing system **110**, and to provide the identified computing resources to the cloud management system **102**.

In embodiments, the network management system **204** can be any type of network management application or tool to securely communicate with the set of resource servers **108** and the computing systems **110**, to monitor the state of the set of resource servers **108** and the computing systems **110**, to retrieve and request data from the set of resource servers **108** and the computing systems **110**, and to manage and direct the set of resource servers **108** and the computing systems **110**. For example, the network management system **204** can be a "FUNC" server as described in U.S. patent application Ser. No. 12/130,424, filed May 30, 2008, entitled "SYSTEMS AND METHODS FOR REMOTE MANAGEMENT OF NETWORKED SYSTEMS USING SECURE MODULAR PLATFORM" (U.S. Patent Application Publication No. 20090300180) assigned to Red Hat Corporation, the disclosure of which is incorporated herein, in its entirety, by reference.

In embodiments, in order to aid in identifying the computing resources, the set of resource servers **108** and/or the computing systems **110** can include a resource monitoring agent. For example, as illustrated in FIG. **2**, the user computing system **116** can include a resource monitoring agent **206**. The resource monitoring agent **206** can be configured to identify the computing resources of the user computing system **116**. The resource monitoring agent **206** can provide the identification of the computing resources to the cloud management system **102** and/or network management system **208**. The resource monitoring agent **206** can be configured to include the necessary logic, routines, instruction, and commands to communicate with the hardware and software resources of the computing systems **110** in order to identify the computing resources of the set of resource servers **108** and/or the computing systems **110**.

In embodiments, the cloud management system **102** and/or network management system **204** can be configured to identify both the hardware and software resources of the set of resource servers **108** and computing systems **110** and which of those resources are available for use in the cloud. The cloud management system **102** can be configured to identify the hardware resources such as type and amount of processing power, type and amount of memory, type and amount of storage, type and amount of network bandwidth and the like, of the set of resource servers **108** and the computing systems **110**. Likewise, the cloud management system **102** can be configured to identify the software resources, such as type of OS, application programs, and the like, of the set of resource servers **108** and the computing systems **110**.

In embodiments, when identifying the computing resources, the cloud management system **102** and/or network management system **204** can be configured to identify the usage and availability of the set of resource servers **108** and the computing systems **110**. For example, the computing systems **110** can be supporting other processes outside the ad-hoc cloud **106** and/or virtual machines in the ad-hoc cloud **106**, and the set of resource servers **108** can be

supporting virtual machines in the dedicated cloud **104**. The cloud management system **102** and/or network management system **204** can be configured to identify both the type and total amount of hardware and software resources as well as those currently available for use in the dedicated cloud **104** and the ad-hoc cloud **106**.

In embodiments, once the computing resources have been identified, the cloud management system **102** can be configured to store an identification of the available resources in the inventory **124** in the repository **126**. The repository **126** can be any type of structure configured to store information, such as a database. The repository **126** can be maintained in a computer readable storage device or medium whether local to or remote from the cloud management system **102**.

In embodiments, the inventory **124** can be configured to include information that identifies the set of resource servers **108** and the computing systems **110** and information identifying the computing resources available. The set of resource servers **108** and the computing systems **110** can be identified by unique identifiers such as, for instance, Internet Protocol (IP) addresses or other addresses. For example, each system **112**, **114**, **116**, and **118** can have a unique identifier. In the inventory **124**, the cloud management system **102** can associate, with each unique identifier, the computing resources available on that computing system. The inventory **124** can include the type and total amount of hardware and software resources and the type and amount of available hardware and software resources.

In embodiments, once identified, the cloud management system **102** can be configured to instantiate the virtual machines, for example a virtual machine **208**, in the dedicated cloud **104** and the ad-hoc cloud **106**, as described above in FIG. **1**. The cloud management system **102** can be configured to utilize any type of cloud management scheme to instantiate the virtual machines on the set of resource servers **108** and/or the computing system **110**. Likewise, the cloud management system **102** can utilize different types of cloud management schemes on different ones of the set of resource servers **108** and/or the computing systems **110**, for instance, depending on which scheme can be supported by a particular one of the set of resource servers **108** and/or computing system **110**. The cloud management system **102** can maintain the VM record **130** of each virtual machine instantiated in the dedicated cloud **104** and the ad-hoc cloud **106**. Each virtual machine can be assigned an instantiated machine ID that can be stored in the VM record **130**. Additionally, the cloud management system **102** can store the duration of each virtual machine and the collection of resources utilized by each virtual machine in the VM record **130** and/or inventory **124**. The cloud management system **102** can maintain the VM record **130** in the repository **126**.

In embodiments, the instantiation and management of virtual machines described above can be performed by the cloud management system **102**. Likewise, the cloud management system **102** can be configured to communicate with one or more VM managers **210** separate from the cloud management system **102**. The cloud management system **102** can be configured to communicate with the separate VM managers **210** in order to provide the VM managers **210** with the computing resources allocated to a particular virtual machine, and the VM managers **210** can be configured to instantiate the virtual machine on the allocated computing resources. The cloud management system **102** can be configured to communicate and cooperate with the VM managers **210** regardless of the cloud management scheme used by the VM managers **210**. For example, the VM managers **210** can be a variety of different VM managers supporting cloud management schemes such as Xen, Kernel-based Virtual Machine (KVM), VMware, mainframe ZVM, and the like.

In embodiments, to manage and instantiate the virtual machines regardless of the cloud management scheme of the dedicated cloud **104** and ad-hoe cloud **106**, the cloud management system **102** can be configured to utilize the abstraction library **200**. The abstraction library **200** can be configured to abstract out the differences between different cloud management schemes. This can include abstracting out any differences between cloud management schemes used to format virtual machines, any differences in the management commands, protocols, APIs etc., and any other differences between different cloud architectures. The abstraction library **200** can be configured to include a record of the different formats, commands, protocols APIs, etc. utilized by the cloud management schemes in order to allow communication, control, instantiation, and management of the virtual machines. Additionally, the abstraction library **200** can be configured to include commands and software instructions to convent the format of one cloud management scheme to another cloud management scheme. The abstraction library **200** can be implemented as any type of software library accessible by the cloud management system **102**, management tools of the cloud management system **102**, and other systems and application programs. The cloud management system **102** can be configured to maintain the abstraction library **200** in a repository or storage, such as the repository **126**. As such, the cloud management system **102** can be configured to instantiate and manage virtual machines regardless of the cloud management scheme utilized by the dedicated cloud **104** and ad-hoc cloud **106**.

In embodiments, the cloud management system **102** can be configured to utilize the abstraction library **200** when instantiating virtual machines in the dedicated cloud **104** and the ad-hoc cloud **106**. The cloud management system **102** can be configured to utilize the abstraction library **200** in order to configure the virtual machines, to generate disk images, operating system images, appliances etc., and to covert the virtual machines from one virtualization scheme to another virtualization scheme when instantiating virtual machines in the dedicated cloud **104** and the ad-hoc cloud **106**. The cloud management system **102** can utilize the abstraction library when instantiating new virtual machines. Likewise, the cloud management system **102** can utilize the abstraction library **200** when migrating virtual machines to or between the set of resource servers **108** and/or the computing systems **110**, for instance, when performing load balancing in the dedicated cloud **104** and ad-hoc cloud **106**.

For example, the dedicated cloud **104** can be supporting the Xen cloud management scheme. When instantiating the virtual machine **208** in the dedicated cloud **104**, the cloud management system **102** can configure the virtual machine **208** to the Xen cloud management scheme. Likewise, in another example, the cloud management system **102** can receive the virtual machine **208** formated to the KVM cloud management scheme. To instantiate the virtual machine in the dedicated cloud **104**, the cloud management system **102** can convert the virtual machine **208** from the KVM cloud management scheme to the Xen cloud management scheme.

In embodiments, the cloud management system **102** can be configured to utilize the abstraction library **200** to communicate with the virtual machines instantiated in the dedicated cloud **104** and the ad-hoc cloud **106** regardless of the cloud management scheme of the clouds. The cloud management system **102** can communicate with the instantiated virtual machines in order to start, stop, suspend, reboot,

query, etc. the virtual machines. For example, the dedicated cloud **104** can be supporting the Xen cloud management scheme and the cloud management system **102** can be using management tools compatible with the ZVM cloud management scheme. The cloud management system **102** can utilize the abstraction library **200** to convert the commands from the ZVM compatible management tools to the Xen cloud management scheme in order to communicate with the virtual machine **208**.

In embodiments, the cloud management system **102** can be configured to utilize the abstraction library **200** to allow third parties to communicate with the virtual machines instantiated in the dedicated cloud **104** and the ad-hoc cloud **106** regardless of the cloud management scheme of those clouds. The third parties can communicate with the instantiated virtual machines in order to start, stop, suspend, reboot, query, etc. the virtual machines. The cloud management system **102** can be configured to provide an interface **212** to receive receive communications from the third parties. The interface **212** can be any type of interface to communicate with third parties or management tools operated by third parties, such as VM managers, management tools, web browsers, network management tools, and the like. The cloud management system **102**, through the interface **212**, can be configured to receive the communication from the third parties in any cloud management scheme and configured to convert the communication to the cloud management schemes of the dedicated cloud **104** and the ad-hoe cloud **106** utilizing the abstraction library **200**.

For example, the dedicated cloud **104** can be supporting the Xen cloud management scheme and the virtual machine **208** can be owned by a requester **214**. The requester **214** can be using management tools compatible with the ZVM cloud management scheme. The requester **214** can establish a link between the management tools and the interface **212** to communicate with the virtual machine **208**. The cloud management system **102**, through the interface **212**, can utilize the abstraction library **200** to convert the communications from the ZVM compatible management tools to the Xen cloud management scheme of the dedicated cloud **104**.

In embodiments, the cloud management system **102** can be configured to manage communications between the virtual machines instantiated in the dedicated cloud **104**, ad-hoc cloud **106**, and/or other clouds regardless of the cloud management scheme. The cloud management system **102** can be configured to establish a messaging bus, web service, or other API between virtul machines and convert any messages or communications to the appropriate cloud management scheme.

For example, the dedicated cloud **104** can be supporting the Xen cloud management scheme and the virtual machine **208** can be instantiated in the dedicated cloud **106**. Likewise, a virtual machine **216** can be instantiated in the ad-hoc cloud **106** and the ad-hoc cloud **106** can be supporting the KVM cloud management scheme. The virtual machine **208** may need to communicate with the virtual machine **216**. For instance, the virtual machine **216** can be providing a service to the virtual machine **208**. The cloud management system **102** can establish a messaging bus **218** between the virtual machine **208** and the virtual machine **216**, through the networks **120** and **122**. The cloud management system **102** can utilize the abstraction library **200** to convert messages from the KVM compatible virtual machine **216** to the Xen cloud management scheme for receipt by the virtual machine **208**, and vice versa.

FIG. **3** illustrates an exemplary diagram of hardware and other resources that can be incorporated in a computing system **300** and configured to communicate with the clouds **104** and **106** via one or more networks **120** and **122**, according to embodiments. In embodiments as shown, the computing system **300** can comprise a processor **302** communicating with memory **304**, such as electronic random access memory, operating under control of or in conjunction with operating system **308**. Operating system **308** can be, for example, a distribution of the Linux™ operating system, such as SELinux, the Unix™ operating system, or other open-source or proprietary operating system or platform. Processor **302** also communicates with one or more computer readable storage devices or media **310**, such as hard drives, optical storage, and the like, for maintaining the repository **126**. Processor **302** further communicates with network interface **306**, such as an Ethernet or wireless data connection, which in turn communicates with one or more networks **120** and **122**, such as the Internet or other public or private networks.

Processor **302** also communicates with the cloud management system **102**, to execute control logic and allow perform the management processes as described above and below. Other configurations of the computing system **300**, associated network connections, and other hardware and software resources are possible.

While FIG. **3** illustrates the computing system **300** as a standalone system including a combination of hardware and software, the computing system **300** can include multiple systems operating in cooperation. The cloud management system **102** can be implemented as a software application or program capable of being executed by the computing system **300**, as illustrated, or other conventional computer platforms. Likewise, the cloud management system **102** can also be implemented as a software module or program module capable of being incorporated in other software applications and programs. Further, the cloud management system **102** can also be implemented as a software module or program module capable of being incorporated in other management software applications and programs. In any example, the cloud management system **102** can be implemented in any type of conventional proprietary or open-source computer language. When implemented as a software application or program code, the cloud management system **102** can be stored in a computer readable storage medium, such as storage **310**, accessible by the computing system **300**.

FIG. **4** illustrates a flow diagram of a flexible management process for a cloud computing architecture, according to embodiments. In **402**, processing can begin. In **404**, the cloud management system **102** can identify a communication for a virtual machine instantiated according to a cloud management scheme. The communication can be formated according to a cloud management scheme different than the cloud management scheme of the virtual machine. The communication can originate with the cloud management system **102**, with a third party such as requester **214**, or another virtual machine.

In **406**, the cloud management system **102** can be configured to convert the communication to the cloud management scheme of the virtual machine. The cloud management system can utilize the abstraction library **200** to convert the communication. The abstraction library **200** can abstract out the differences between different cloud. The abstraction library **200** can include the different formats, commands, instructions, APIs utilized by the cloud management schemes in order to allow communication, control, instantiation, and management of the virtual machines. Additionally, the abstraction library **200** can include commands and

software instructions to convent the format of one cloud management scheme to another cloud management scheme.

In **408**, the cloud management system **102** can provide the converted communication to the virtual machine. Then, in **410**, the process can end, but the process can return to any point and repeat.

FIG. **5** illustrates a flow diagram of another flexible management process for a cloud computing architecture, according to embodiments. In **502**, processing can begin. In **504**, the cloud management system **102** can identify a virtual machine to instantiate on a computing system supporting a cloud management scheme. For example, the virtual machine can be a new virtual machine to instantiate on the set of resource servers **108** and/or computing systems **110**. Likewise, the virtual machine can be a virtual machine to migrate to or between one or more the set of resource servers **108** and/or computing systems **110** utilizing a different cloud management scheme.

In **506**, the cloud management system **102** can configure the virtual machine for the cloud management scheme of the computing system. The cloud management system can utilize the abstraction library **200** to configure the virtual machine. The abstraction library **200** can abstract out the differences between different cloud management schemes. The abstraction library **200** can include the different formats, commands, instructions, APIs, etc. utilized by the cloud management schemes in order to allow communication, control, instantiation, and management of the virtual machines. Additionally, the abstraction library **200** can include commands and software instructions to convert the format of one cloud management scheme to another cloud management scheme.

In **508**, the cloud management system **102** can instantiate the virtual machine on the computing system. Then, in **510**, the process can end, but the process can return to any point and repeat.

Certain embodiments may be performed as a computer application or program. The computer program may exist in a variety of forms both active and inactive. For example, the computer program can exist as software program(s) comprised of program instructions in source code, object code, executable code or other formats; firmware program(s); or hardware description language (HDL) files. Any of the above can be embodied on a computer readable medium, which include computer readable storage devices and media, and signals, in compressed or uncompressed form. Exemplary computer readable storage devices and media include conventional computer system RAM (random access memory), ROM (read-only memory), EPROM (erasable, programmable ROM), EEPROM (electrically erasable, programmable ROM), and magnetic or optical disks or tapes. Exemplary computer readable signals, whether modulated using a carrier or not, are signals that a computer system hosting or running the present teachings can be configured to access, including signals downloaded through the Internet or other networks. Concrete examples of the foregoing include distribution of executable software program(s) of the computer program on a CD-ROM or via Internet download. In a sense, the Internet itself, as an abstract entity, is a computer readable medium. The same is true of computer networks in general.

While the teachings has been described with reference to the exemplary embodiments thereof, those skilled in the art will be able to make various modifications to the described embodiments without departing from the true spirit and scope. The terms and descriptions used herein are set forth by way of illustration only and are not meant as limitations. In particular, although the method has been described by examples, the steps of the method may be performed in a different order than illustrated or simultaneously. Furthermore, to the extent that the terms "including", "includes", "having", "has", "with", or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term "comprising." As used herein, the term "one or more of" with respect to a listing of items such as, for example, A and B, means A alone, B alone, or A and B. Those skilled in the art will recognize that these and other variations are possible within the spirit and scope as defined in the following claims and their equivalents.

What is claimed is:

1. A method comprising:

identifying a virtual machine that is configured in accordance with a first cloud management scheme;

abstracting, by a processor of a computing system, differences of management protocol between the first cloud management scheme and a second cloud management scheme;

reconfiguring, by the processor, the virtual machine from the first cloud management scheme to the second cloud management scheme in view of the abstracted differences; and

creating an instance of the reconfigured virtual machine.

2. The method of claim **1**, wherein the reconfiguring is further in view of an instruction to configure the virtual machine in accordance with the second cloud management scheme.

3. The method of claim **1**, further comprising receiving the virtual machine to instantiate on the computing system.

4. The method of claim **1**, further comprising migrating the virtual machine from an original computing system to the computing system.

5. A computing system comprising:

a memory to store an abstraction library; and

a processor, operatively coupled with the memory, to:

identify a virtual machine that is configured in accordance with a first cloud management scheme;

abstract differences of management protocol between the first cloud management scheme and a second cloud management scheme;

reconfigure, in view of the abstraction library, the virtual machine to the second cloud management scheme in view of the abstracted differences; and

create an instance of the reconfigured virtual machine.

6. The computing system of claim **5**, wherein to reconfigure is further in view of an instruction to configure a virtual machine in accordance with the second cloud management scheme.

7. The computing system of claim **5**, wherein the processor is further to receive the virtual machine to instantiate on the computing system.

8. The computing system of claim **5**, wherein the processor is further to migrate the virtual machine from an original computing system to the computing system.

9. A non-transitory computer readable storage medium comprising instructions encoded thereon that, when executed by a processor, cause the processor at least to:

identify, by the processor, a virtual machine that is configured in accordance with a first cloud management scheme;

abstract, by the processor, differences of management protocol between the first cloud management scheme and a second cloud management scheme;

reconfigure, by the processor, the virtual machine to the second cloud management scheme in view of the abstracted differences; and

create, by the processor, an instance of the reconfigured virtual machine.

10. The non-transitory computer readable storage medium of claim **9**, wherein the reconfiguring is further in view of an instruction to configure, by the processor, the virtual machine in accordance with the second cloud management scheme.

11. The non-transitory computer readable storage medium of claim **9**, wherein the processor is further to receive, by the processor, the virtual machine to instantiate on the processor.

12. The non-transitory computer readable storage medium of claim **9**, wherein the processor is further to migrate, by the processor, the virtual machine from an original processor to the processor.

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